BIONOMICS AND CONTROL OF THE SUPERB PLANT BUG, *ADELPHOCORIS SUPERBUS* (UHL.) (MIRIDAE) IN SOUTHERN ALBERTA

by

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BIONOMICS AND CONTROL OF THE SUPERB PLANT BUG, *ADELPHOCORIS SUPERBUS* (UHL.) (MIRIDAE) IN SOUTHERN ALBERTA

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ABSTRACT

The investigations described in this thesis were conducted in alfalfa seed-fields of the Scandia district, and at the Science Service Laboratory, Lethbridge. The purpose of the research was to gain information that would aid in the control of a pest bug of alfalfa, *Adelphocoris superbus* (Uhl.).

Laboratory tests and field observations proved that the species is well adapted to its environment in southern Alberta. Data concerning relative positions of overwintering eggs as they were found in alfalfa stems revealed that 59.5 per cent of 1260 eggs collected in the field in the fall of 1951 were laid in the upper four inches of the alfalfa stems. The majority of eggs will therefore be spread back on the fields with the plant materials after harvesting, where they will normally be protected by snow cover. Tests also proved that the eggs are very resistent to freezing temperatures.

Only one generation developed per year in southern Alberta, although two per year have been recorded in Utah. An obligatory diapause prevented fall hatch and subsequent high mortality because of freezing temperatures. A long hatching period of

more than six weeks was evident each season.

A. superbus was effectively controlled by early spring burning of the alfalfa fields and by low dosages of the chlorinated hydrocarbons, Toxaphene and DDT. Burning eliminated two valuable predators, but reduced the incidence of plant diseases and produced healthier stands of alfalfa.

PREFACE

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I INTRODUCTION

Alfalfa is grown for seed in southern Alberta principally along the perimeters of the irrigated districts of the mixed prairie. Only those farmers whose land borders on large tracts of unbroken prairie have been successful alfalfa seed producers in these districts. Certain ground-nesting species of leaf-cutter bees live on the prairie and provision their cells with alfalfa pollen. In obtaining this pollen they trip and cross-pollinate the alfalfa florets with amazing efficiency, and this results in cross-pollinated seed being set on a commercial scale.

Certain pest insects of the genera *Lygus* and *Adelphocoris* can seriously reduce the amount of bloom. They feed on the unopened bud clusters causing them to whiten and die. This damage is termed "bud blasting". They have also been credited with causing flower-drop, stunting of plants, and the destruction of immature seed in alfalfa fields. When these bugs are numerous they are able to keep fields from putting forth enough bloom to serve the needs of the pollinators in the vicinity. In such numbers they are of economic importance to the seed-

producer because the efficiency of the pollinating bees is increased by having an adequate amount of bloom on the fields during their flight period. The number of bugs constituting an economic population varies probably inversely with the size of the pollinator population in the same area.

While conducting alfalfa pollination studies in the Scandia area of southern Alberta it was noted that a pest species, Adelphocoris superbus (Uhl.) was causing serious depletion of bloom in certain seed fields. Because little information was available on the bionomics and control of this species, a study of this pest seemed essential in the program of improving alfalfa seed growing in western Canada.

II LITERATURE REVIEW

A. ORIGINAL DESCRIPTION, TAXONOMIC POSITION AND DISTRIBUTION

This species of mirid bug was first described and named Calocoris superbus by Uhler, 1875. His original description is as follows:-

> "A Calocoris (superbus, sp. nov.) which I have provisionally separated from C. rapidus Say,

may be the extreme limit of bright color attained by that species. I suspect this to be the case, because specimens of that species, from the less considerable elevations in Colorado Territory, retain the black spots of the pronotum and some of the fuscous-grey of the hemelytra which one obtains in the specimens from the Atlantic region.

Having the same form and general characters as C. rapidus Say. it differs however, in being bright scarlet; the rostrum extending only to the posterior line of the middle coxae; the antennae black and having only the base of the third joint pale; the scutellum blood-red, with the lateral margin broadly black; the areole of the membrane deeply infuscated; the pectus orange-red; and the middle of the ventor blackish. Legs black, but with pale yellowish coxae. Tergum a little infuscated, length, 7½ millimeters; breadth across humeri, 2¾ millimeters. One female from Owen's Valley, California."

The generic name of this species was later revised to Adelphocoris. It is at present known as Adelphocoris superbus

(Uhler), of the family Miridae and the order Hemiptera.

Blatchley (1926) endorsed the relationship between A. rapidus and A. superbus suggested by Uhler in that he believed, from examinations of series of the bugs, that A. superbus was merely the western variety of A. rapidus. This appears to be borne out in the Canadian prairie provinces where A. superbus, found in southern Alberta, is supplanted by A. rapidus in Saskatchewan. In the Scandia area of southern Alberta there is considerable color variation among adults of this species. Specimens have been found that range in color from bright scarlet to pale yellowish-brown. All have been identified as A. superbus, however. Sorenson (1946) stated that A. superbus was probably a new-world species and native to western United States, pointing out that it had been recorded from Arizona, Colorado, Iowa, Kansas, New Mexico and Utah.

B. ECONOMIC IMPORTANCE AND CONTROL

Townsend (1893) reported that this species was numerous on alfalfa. Both adults and nymphs were seen and were probably causing considerable injury to the plant. Sorenson (1932), as a result of cage experiments using the tarnished plant bug, Lygus pratensis Linn. and the superb plant bug,

concluded that damage caused by these pests constituted one of the environmental factors responsible for the flower drop of alfalfa that occurs in the open field.

Carlson (1940), experimenting with Lygus hesperus Knight and Lygus elisus Van Duzee on caged alfalfa reported that damaged buds showed discoloration and evidence of deterioration within 24 to 48 hours after injury. He stated that "a rapid disintegration of the buds that apparently results from a toxic substance emitted with the saliva of the feeding insects follows injury."

Hughes (1943), obtained comparable results using Adelphocoris lineolatus (Goeze), Adelphocoris rapidus (Say) and Lygus oblineatus (Say) on caged alfalfa.

Sorenson (1944) found that the nature of the injury inflicted by the superb plant bug was similar to that described for Lygus bugs, i.e., their feeding significantly altered the growing seed crop by (1) decreasing the vegetative growth of young plants; (2) distorting it as the plants grow older and (3) increasing the amount of bud-blasting, blossom-drop and shrivelled seed. He also intimated that the superb plant bug, possibly due to its larger size or the toxemia induced, caused a greater amount of injury than Lygus when the degree of infestation was approximately the same.

Jeppson and MacLeod (1946), as a result of experiments in which Lygus elisus and Lygus hesperus were caged over young alfalfa plants, discovered that during the vegetative growing period of the stems areas of injury were usually found to occur at the terminal growing point and lateral bud primordia. They concluded that stem growth continued in such cases by the stimulation of uninjured lateral buds to replace the injured growing points. Injured plants were darker in color, the leaves more ovate, crinkled and misshapen than the leaves on healthy plants. In cases of extreme injury the leaves were very small, the internodes short and the stems thin and crooked.

Sorenson (1946) reiterated statements made in his earlier publications but stated that, with the discontinuation in recent years of the practice of growing seed on first-growth alfalfa, superb plant bug numbers had become so reduced that damage by the insect was negligible. He assumed that when the first growth alfalfa was cut, few if any of these bugs had reached the adult stage. Eggs and nymphs, were destroyed in large numbers by the cutting of the alfalfa. All of Sorenson's work was done in Utah.

Hobbs (1948), working in the irrigated section of southern Alberta, found that in certain alfalfa seed-fields large populations of the bugs had built up and were causing

considerable damage to the alfalfa. In one such field an average of 2.14 superb plant bugs were taken per sweep. This population of A. superbus, combined with lack of water, kept the field from blossoming until late in July. Hobbs also observed that a common practice among the successful alfalfa-seed growers of southern Alberta was to burn, harrow, or to disc their fields in early spring. These practices, he concluded, must have had a very harmful effect on the overwintering superb plant bug eggs. Hughes (1943), experimenting with a closely related species of this bug, Adelphocoris lineolatus (Goeze), arrived at the conclusions that cultivation seemed an ineffective control, and that it had to be thorough to accomplish even a minimum of good. On the other hand he found that spring burning if done thoroughly would successfully control both, A. lineolatus and A. rapidus, in Minnesota.

Besides being a pest of alfalfa, A. superbus causes a great deal of damage to cotton in the southern States. Eyer and Medler (1942) set up experiments to test the value of certain arsenical and sulphur insecticides on the superb plant bug, which they noted was a serious pest of cotton in southern New Mexico, causing distortion of the boll coverings and staining of the lint. Substantial increases in yield of seed cotton were obtained with dusts of paris green or calcium arsenate, with sulphur. These insecticides also produced high mortalities in

caged insects. Stevenson and Kauffman (1948), working in Arizona, stated that the most serious problem in growing cotton was the control of certain plant bugs and stink bugs which included A. superbus. The dusts they used included 5 per cent DDT in sulphur, 10 per cent DDT in sulphur and BHC dust containing 2.5 per cent of the gamma isomer applied both by airplane and by hand. The results were based on the effectiveness of the insecticides against cotton insects in general and the increases in yields. Five per cent DDT in sulphur was the most satisfactory insecticide for general use against cotton insects in Arizona.

C. TOXICITY OF INSECTICIDES TO ALFALFA POLLINATORS

Many research workers, including Piper et al. (1914), Tysdal (1940), Tysdal, Kesselbach and Westover (1942), Jones and Olson (1943), Pharis and Unrau (1953), and Hobbs (1952) have concluded that alfalfa florets must be tripped and cross-pollinated to obtain a seed-crop of commercial importance. The evidence that bees are the main agents responsible for the seed-set appears indisputable.

Despite many reports of the value of honeybees as pollinators of alfalfa in the United States, Hobbs (1952) proved that in southern Alberta these bees were of little or no value

in the production of alfalfa seed. Gray (1925) and Salt (1940), both working in southern Alberta, theorized that tripping of alfalfa was done by long-tongued bees such as leaf-cutters and bumblebees. Salt proposed means of increasing their numbers and efficiency. Peck and Bolton (1946), working in the parkland of northern Saskatchewan, discussed alfalfa seed production in that area as affected by native bees with a report on means of increasing their numbers. The two most important alfalfa pollinators they recorded are a ground-nesting species, M. latimanus Say. and a log-nester, M. frigida Smith. Hobbs and Lilly (in press) stated that in western Canada seed-growers must rely on the wild bees to pollinate alfalfa and that in the mixed prairie region of southern Alberta two species of ground nesting leaf-cutters, Megachile perihirta Ckll. and Megachile dentitarsus Sladen are the most important pollinators of this crop. These two species are solitary in habit, each female building and provisioning her own tunnels and cells. It is evident that because of this solitary nature, the size of the succeeding generation could be drastically reduced by the ill-timed application of a non-selective insecticide during the flight period of the bees. The flight periods of the bees mentioned above are relatively short, M. perihirta flying from approximately June 20 to July 20 and M. dentitarsus from

approximately July 20 to the end of August.

When spraying for pest insects in alfalfa, the importance of the pollinators must ever be kept in mind. The necessary selective insecticides should only be applied at such time and in such concentration as will result in a minimum of mortality to those pollinating species that are present in the immediate vicinity.

A great deal of controversial literature concerning the relative toxicities of various chlorinated hydrocarbons to bees is available. Hocking (1950) intimated that the confusion arises from the very large number of factors involved and from the tremendous range of variation of some of these factors. He reported that variable factors in the insecticide, the vegetation, the bee and the beekeeper all influence the results obtained from the application of insecticides. The trend of research, however, seems to indicate that both toxaphene and DDT are in the group of insecticides which, when properly applied, are only moderately toxic to bees.

In most of the literature dealing with toxicity of insecticides to bees, research workers used honeybees as experimental insects. Linsley and MacSwain (1947) concluded that on the basis of observations during the 1945 and 1946 seasons, no large scale honeybee mortality had as yet been demonstrated in the field following an application of DDT dust

to blooming alfalfa. They expressed the possibility that depressions in honeybee populations following application of certain insecticidal dusts may be largely or partially the result of repellent action. This same conclusion was reported by Smith et al. (1948) after they had dusted an alfalfa field in bloom three times with 30 pounds of 5 per cent DDT dust per acre per application. They noted that the marked decline in honeybee populations following these dustings seemed to be largely due to repellent action of DDT dusts. However, they suggested that even though the effect on the bees was not great, dusting of alfalfa in bloom should be restricted to the essential minimum and should be done only in the early morning before the bees are active.

Weaver (1949), after exposing caged honeybees to insecticidal dusts, concluded that toxaphene was practically non-toxic. Twenty per cent toxaphene with 40 per cent sulphur gave only a 5 per cent mortality at 36 pounds per acre. Weaver (1951) found that in field tests when exposing honeybees to sprays and dusts of various insecticides a decreasing order of toxicity was obtained with 3 per cent Gamma BHC with 5 per cent DDT dust, BHC dust, toxaphene with DDT spray, chlordane dust, toxaphene dust, DDT dust, and toxaphene spray. Dusts were applied in eight weekly treatments in dosages ranging from

10 to 40 pounds per acre. The same number of applications of toxaphene and toxaphene - DDT (2-1) sprays were applied in dosages ranging from 2 to 5 pounds of technical insecticide per acre. He also found from laboratory tests involving the spraying of insecticides directly on the bees that BHC with DDT, BHC, chlordane, DDT and toxaphene were decreasingly toxic. The median lethal dosage of gamma BHC was 0.020 pound per acre, of the BHC with DDT mixture at 0.015 pound per acre. Median lethal dosage of chlordane was 0.038 pound per acre, of DDT was 0.089 pound per acre. The MLD of toxaphene spray was 0.224 pound per acre. Carlson et al. (1950) recommended that DDT could be used on alfalfa when it was in the bud stage but that only toxaphene was recommended for use on seed alfalfa in bloom. It was to be applied between 7 P.M. and 7 A.M. It was explained that toxaphene, when applied between these hours killed only small percentages of honeybees and was considered relatively safe for bloom-period treatments.

In one of the latest papers (Anderson and Tuft, 1952) toxaphene was recommended during hot weather because it seemed to remain effective for lygus bug control during extreme temperature conditions and appeared to be less toxic than DDT to honeybees. Their recommendation was that materials more toxic to honeybees than DDT should be used with extreme caution and that materials less toxic than DDT might be used

with safety.

Some work has been done with wild bees but the published results are inconclusive. Way and Synge (1948) found that Bombus pratorum L., Andrena spp., and Osmia rufa L. were apparently unaffected by short exposures to apple and coton-easter blooms treated with low concentrations of DDT dusts and sprays. Bohart and Lieberman (1949) found that after treating an alfalfa field with 3 per cent DDT dust at the rate of 20 pounds per acre,"over 2 per cent of the females of Nomia melanderi Ckll. nesting in the sample areas were found dead at their nest entrances and about 15 per cent of the nests in the same areas became inactive."

Linsley, MacSwain, and Smith (1950), testing the comparative susceptibility of wild bees and honeybees to DDT, found that in a preliminary series of tests one species each of Nomia, Megachile, Melissodes, Anthidium and Agapostemon exposed to DDT-treated screens in small cages for varying periods and concentrations were more resistant than honeybees at the same exposures and concentrations.

III BIONOMICS OF ADELPHOCORIS SUPERBUS IN SOUTHERN ALBERTA

A. EGG STUDIES

Because this phase seemed to offer the best possibilities for control emphasis was placed on this portion of the bionomics. Previous to this study, eggs had never been found in alfalfa in

southern Alberta.

1. Description of Egg and Oviposition Sites

Sorenson (1946) stated that this species overwintered in the egg stage in Utah, the eggs laid singly but usually close together in various parts of alfalfa stems, branches, leaves and petioles. Hobbs (1948) theorized that the bug in southern Alberta feeds and therefore probably lays its eggs almost exclusively on alfalfa.

The objective of this section was to discover eggs in the host plants, describe their physical characteristics and the oviposition sites chosen by the female bugs in alfalfa plants in southern Alberta.

Methods and Procedure: On June 18, 1951, a heavy infestation of A. superbus was discovered by sweeping an alfalfa seed field in the Scandia area. This field had been under yearly observation since 1945 when a high population of the bugs had done severe damage and had apparently been controlled by burning-off the field the following spring. It had taken the bugs five years to build up to economic proportions again. The situation in 1951 offered an opportunity to test some of the insecticides against the bugs and to study the bionomics of the species. The experiments with insecticides are described in the section on Control.

In the late summer of 1951, A. superbus adults were placed on maturing alfalfa plants under round, screen-wire cages to confine oviposition. Each cage was one foot in diameter and three feet high. The cages were left over the plants in the field during the growing season. When the growing season was completed the caged plants were brought to the laboratory and kept at 0° C until they could be examined for the presence of eggs.

Examination was made with the aid of a low power (12x) binocular microscope. Eggs dissected from gravid females, and illustrations of Adelphocoris lineolatus eggs (Hughes, 1943) aided in the search. Over a period of months hundreds of eggs were discovered and stored at 0° C for future experiments. Data on the width and type of stem selected, and the relative positions of eggs in plants were compiled. A micrometer calliper was used to determine stem widths, all the measurements being made under low power magnification. More than one egg at a given site showed oviposition preference and this fact was taken into account when analyzing the data.

Additional data were obtained late in the fall of 1951 by examining plant samples that had been taken at random from a second field in the Scandia area that had a heavy infestation of Adelphocoris superbus. The yield on this field was so poor

that the owner, Mr. H. Taylor, had left the alfalfa standing in the field. Data were compiled concerning oviposition sites in open field alfalfa so that comparison could be made with the cage data of the same season.

In the fall of 1952 cages similar to those used in 1951 were set out in Taylor's alfalfa field and stocked with A. superbus adults from the surrounding alfalfa in order to have data for a two year period on sites of oviposition. All material collected was examined in a similar manner.

Results: Eggs of A. superbus are seen in figures 1 and 2. The oval egg caps are very minute and appear as tiny specks on the surface of the stem when viewed with the nakedeye. They project slightly above the surface of the stem. It is virtually impossible to discover them without magnification, especially if, as with alfalfa in the two fields studied, lesions caused by the black stem fungus, Ascochyta imperfecta, are prevalent on the plants.

Eggs averaged approximately 1.3 mm. in length and 0.3 mm. in the widest portion. They are roughly bean-shaped, cylindrical, and have a smooth, shiny chorion. There is a definite lateral constriction in the egg at the point where it is held firmly in the wall of the alfalfa stem. This constricted area is present in dissected eggs. The chorion surrounding this region appears thicker than on the rest of the egg, and is opaque. The

contents in undeveloped eggs are pale orange and granular in consistency.

Results of the analyses of data on stem-width preferences are outlined in Table 1. A statistical comparison of these results (using the formula $t = |\bar{x}_1 - \bar{x}_2| / S_{\bar{d}}$) revealed no significant difference between cage and open-field data in 1951, and no significant difference between the cage data of 1951 and 1952.

Invariably oviposition sites were in squared stems and branches, either in secondary growth or in the upper portions of older plants. The relative positions of eggs in the alfalfa plants are recorded in table 2.

Although the act of oviposition by these bugs has never been observed in southern Alberta, certain assumptions can be drawn from the data obtained. Hughes (1943) observed that occasionally a female of A. lineolatus tried without success to oviposit in the tougher portions of alfalfa plants. The ovipositor was then withdrawn and the insect moved forward to another position on the plant. A. superbus females too have a preference for the thin walled, square stems which afford less resistance to insertion of the ovipositor. The flat walls of these stems seem to be the preferred sites for oviposition and here the vast majority of the eggs are laid. Occasionally, scars are observed in the stem below the point where egg caps

Fig. 1 External view of egg caps of A. superbus (Uhl.) in alfalfa stem. (photomicrograph approximately X30)

Fig. 2 Longitudinal section through an alfalfa stem showing eggs of A. superbus (Uhl.) within. (photomicrograph approximately X18)

Table 1.

Comparison of Diameters of Alfalfa Stems Containing A. superbus Eggs, Scandia, Alta.

Origin of Alfalfa	Year	No. of measurements	Mean width (mm.)	S*	Sx**	Range (mm.)
CAGED	1951	180	1.0401	0.2819	0.0210	0.45 to 2.15
OPEN FIELD	1951	100	1.0717	0.2545	0.0255	0.69 to 1.75
CAGED	1952	285	1.0080	0.2275	0.0135	0.49 to 1.70

* Standard deviation

** Standard error of a mean

Table 2

Relative Positions of *Adelphocoris superbus* Eggs in Alfalfa Plants, Scandia, Alberta.

Origin of alfalfa	No. of eggs examined	Percentage of Eggs found in					
		Upper 4" of stem	5" to 8" from tip of stems	9" to 12"	Basal 4" of stems	Upper branches	Debris
CAGED, 1951.	295	43.1	22.0	7.5	3.5	20.7	3.0
OPEN FIELD, 1951.	1260	59.5	10.4	1.0	0.0	16.7	12.4
CAGED, 1952.	266	62.4	18.1	5.2	0.0	10.9	3.3

are seen and these probably represent spots where the ovipositor has been withdrawn and no egg deposited due to the tougher plant tissue. No eggs were ever found in the more matured and lignified rounded portions of the stems.

The evidence in table 1 shows that the bugs chose a definite range of stem widths in which to oviposit. There were no significant differences in the widths selected, whether the material was from cages or the open field. (mean width approximately 1.0 mm. in all instances)

2. Cold-hardiness of A. superbus Eggs

Salt (1950) conducted a study of time as a factor in freezing of undercooled insects. He concluded that, for over-wintering insects, protection is not always complete. The result is that those individuals in more exposed hibernacula and with the least ability to undercool perish. In severe winters the magnitude of this group may be sufficient to reduce the population seriously.

Surrounding dead plant tissue and snow cover normally afford ample protection against low temperatures for overwintering eggs of the superb plant bug. Chinook winds in the Scandia area, however, occasionally remove much of the snow cover and expose the eggs to direct weather effects.

In view of the variable weather conditions to which the overwintering eggs are exposed at times, experiments were commenced to test the cold-hardiness of the eggs, and to determine the mortality that might occur in the field during winter.

Methods and Procedure: Data were obtained from field observations and laboratory tests.

Eggs collected from the field in the spring of 1952 were examined for mortality. They were assumed to be normal if they were turgid and the contents were granular in appearance.

Eggs collected in the field in the fall were tested in the laboratory for cold-resistance. All eggs were left in the host tissues and stored in closed jars at 0° C. until tested.

Cold treatment was administered in a thermostatically-controlled freezing cabinet. Eggs were segregated into small groups and exposed to various combinations of time and temperature. All temperatures used in testing were below 0° C. : -20, -31, -33, -36, -41, and -45. At each of these temperatures groups of eggs were exposed for various lengths of time from a minimum of one hour to a maximum of 30 days. Only small groups of four or five eggs were used in preliminary tests until the approximate freezing ranges were established. When this was determined a minimum of 10 eggs per sample was used.

Eggs were removed from plant stems after exposure and

examined. Freezing caused a globulation of the egg contents which was visible at low-power magnification with transmitted light.

Results: Eggs brought directly from the fields in the spring were all in good condition. This was not surprising, however, because the winter of 1951-52 was very mild. The lowest temperature recorded in southern Alberta for that season was -14° F. (-25.56° C.) but generally the temperature was well above zero.

Results of the laboratory tests are summarized in table 3. The trend of freezing in the laboratory-tested eggs followed the pattern recorded by Salt (1950) when he exposed Cephus cinctus larvae to undercooling. Freezing was the result of a combination of time and temperature. As the temperature was lowered the time needed to freeze eggs became shorter. The tests indicated that A. superbus eggs exhibited a high degree of cold resistance although individuals showed considerable variation in their ability to undercool. This fact was especially noticeable within the groups exposed to -33° C. and -41° C., although at the latter temperature the over-all mortality trend was evident. At this temperature no appreciable differences in percentages of mortality were noted between exposures of 12 to 24 hours duration. After 48 hours exposure however no

Table 3.

Mortality of *Adelphocoris superbus* eggs when exposed to time-temperature treatments

Temperature of exposure (± 1° C.)	No. of eggs per treatment	Period of exposure (hours)	Percentage of eggs frozen
-20° C.	6	168	0.0
	21	720	10.5
-31	7	72	0.0
	14	360	50.0
-33	10	24	0.0
	12	72	16.7
	21	144	0.0
	15	216	0.0
-36	4	8	0.0
	14	24	100.0
-41	10	1	40.0
	19	2	78.9
	23	3	65.2
	25	6	68.0
	42	12	92.3
	49	18	93.9
	22	24	86.3
	35	48	100.0
-45	27	1	85.2
	25	4	100.0

cold-resistance was in evidence. When the temperature was lowered to -45° C., the time needed to freeze eggs was decidedly shortened, 4 hours exposure giving the same mortality as 48 hours at -41° C. There are discrepancies shown in the table, e.g., there was complete mortality at -36° C. for 24 hours. Any unexpected variation such as this could have occurred because of the random origin of the egg batches with possible differences in moisture content. This would affect the degree of resistance exhibited. The batches might contain varying proportions of resistent eggs that would also affect results. The results should have been supplemented by further testing but exhaustion of egg supplies made this impossible.

3. Diapause in Eggs

Hobbs (1948) observed that during the season of 1947, there was no second nymphal peak although the great majority of superb plant bugs had reached maturity before the latter part of July. He suspected that there was only one complete generation a year. Sorenson (1932) stated that the same species had three to four broods per season in Utah but in a later report in 1946 he suspected that probably two generations develop annually there. In view of these differing conclusions concerning the same species it seemed probable that if Hobbs' theory were correct, eggs laid in late summer in southern Alberta either had a very slow rate of

development or an obligatory diapause. This would insure against late fall hatching and consequent death by freezing. To test this theory it was necessary to determine the stage of development attained by the eggs before the onset of winter and whether there was evidence of diapause.

Methods and Procedure: Alfalfa plants were taken at irregular intervals during the fall of 1951 and the spring of 1952, from the unharvested Scandia field mentioned previously. Sampling was done with a square-foot quadrat. Field samples were collected as late as November 27 and as early in the spring as April 24.

Eggs found in these samples were removed from the stems, placed in water and examined for visible signs of embryological development, using low-power magnification and transmitted light. Eggs were separated into three categories: those with no visible embryological development, those showing some visible development, and those almost fully developed and showing varying degrees of pigmentation. Counts were compiled on a percentage basis for comparison. A. superbus embryos develop by involution.

In conjunction with the above test, other field-collected eggs were placed in stoppered containers; a check group of 100 eggs or more was kept at room temperature while a second group of comparable size was exposed to a cold treatment ($37 \pm 2^{\circ}$ F.) for 140 days after which they too were removed to room temperature.

Both groups were moistened at frequent intervals.

Results: Development noted in field-collected eggs is summarized in table 4. No visible signs of embryological development were evident in any of the eggs collected in the fall or in the early spring. No eggs hatched within the check group but within the group which was exposed to cold treatment, 67 per cent of 118 eggs hatched. The remainder of these eggs, and all of the eggs used as checks appeared to be desiccated on examination. Test eggs hatched over a period of 45 days, beginning 16 days after being brought to room temperature.

B. RATE OF NYMPHAL DEVELOPMENT IN THE FIELD

The paper by Sorenson (1946) is the most comprehensive account of work done on the life history of this bug as it is found in the United States. He describes the nymphs as being usually blood-red with some black, but adds that variations occur in which the red color is replaced by green. He also reported that in developing to the adult form, the young pass through five nymphal-instars and that in rearing cages, the total time required for complete development of all nymphal instars was 26 days.

Observations in southern Alberta indicate that the most noticeable variation in color is one in which only the red of

Table 4.

Stages of development in over-wintering eggs of A. superbus, Scandia, Alta. 1951-52.

Date collected from field	No. of eggs examined	Percentage hatched	Percentage of eggs showing		
			Extensive development	Some development	No development
11-X-51	200	0.0	-	-	100.0
7-XI-51	300	0.0	-	-	100.0
27-XI-51	100	0.0	-	-	100.0
22-IV-52	50	0.0	-	-	100.0
13-V-52	50	6.0	6.0	4.0	84.0
29-V-52	47	27.7	12.7	38.3	21.3
17-VI-52	35	62.8	8.5	8.5	20.0

the thorax is replaced with green. Most of the nymphs, however, are characteristically blood-red with contrasting black becoming noticeable in the latter instars.

This portion of the research was initiated to illustrate the development of the population as the season progressed and also to test Hobbs' theory that there was only one complete generation of the bug in southern Alberta.

Methods and Procedure: Sweeps were made at irregular intervals in untreated alfalfa fields in the Scandia area. The A. superbus bugs captured were segregated by instars and the percentage of each instar was recorded. Identification of the various instars is not difficult, the criteria being differences in size and shape, and in the extent of wing development (fig. 3). The wing buds appear first in the third instar of the nymph.

Results: The results for the two seasons are found in tables 5 and 6. The percentage figures in tables 5 and 6 are slightly misleading in a few instances owing to differences in the numbers of bugs collected and in weather conditions at the time of sweeping. This is especially evident in late fall counts e.g. those of September 19, 1952. At this late date the adults had for the most part laid over-wintering eggs and disappeared so that total numbers were very low and the percentage of fifth-

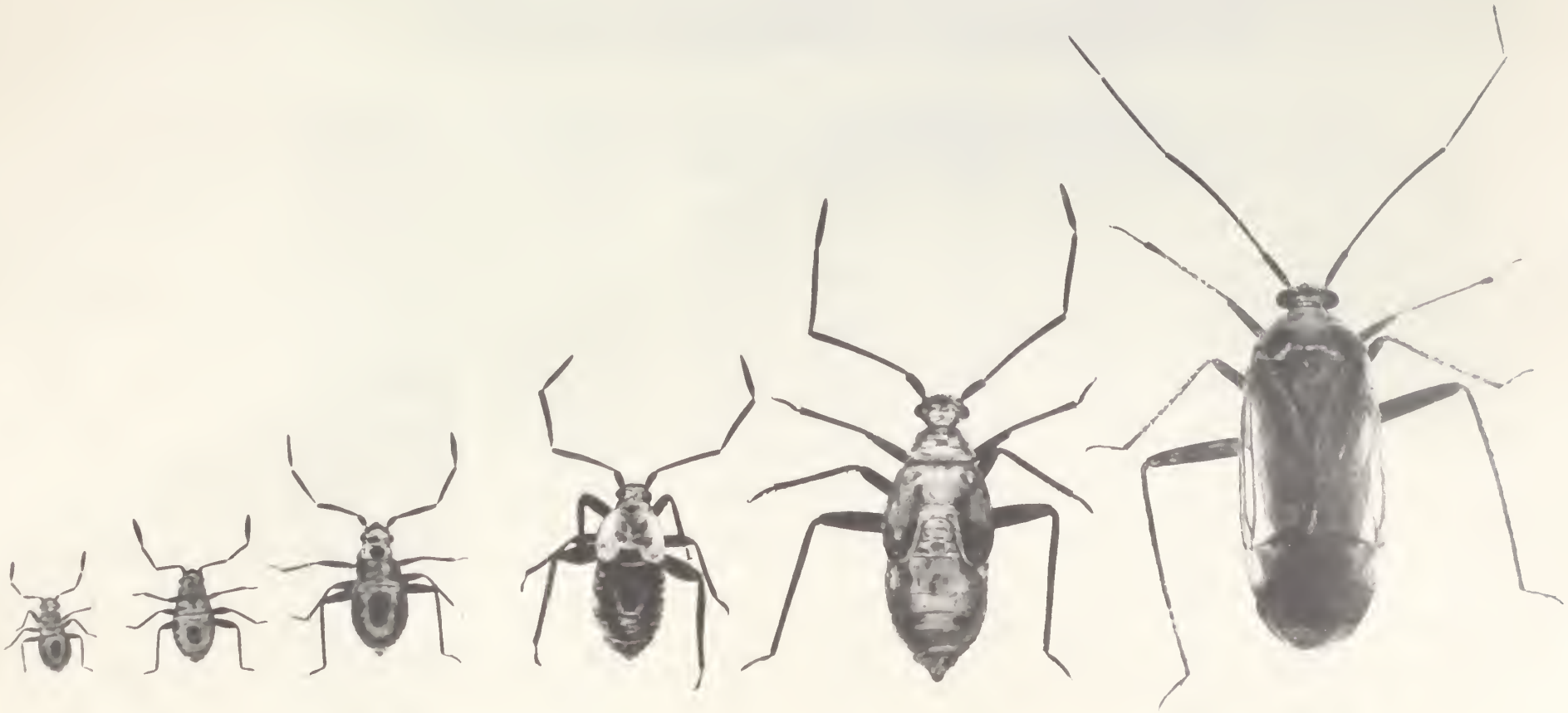

Fig. 3 Nymphs and adult of A. superbus showing progression in size and development (photomicrograph X8)

Table 5

Development of A. superbus, Scandia, Alberta, 1951

Date of sweeping	No. of bugs	% of Nymphal Instars					% of Adults
		First	Second	Third	Fourth	Fifth	
18-V1-51	147	54.4	28.0	13.6	4.0	-	-
29-V1-51	276	31.5	33.3	23.2	9.1	2.9	-
1-V11-51	75	22.7	16.0	25.3	26.6	9.4	-
3-V11-51	50	16.0	12.0	24.0	38.0	10.0	-
12-V11-51	212	27.2	44.6	9.0	7.0	11.7	0.5
17-V11-51	184	19.0	29.3	20.1	15.4	12.5	3.7
26-V11-51	192	0.5	0.5	21.9	49.4	12.5	15.6
6-V111-51	127	-	-	3.1	4.7	21.2	71.0
13-V111-51	82	-	-	-	1.2	7.3	91.5
7-1X-51	240	-	-	-	-	1.2	98.8

Table 6.

Development of A. superbus, Scandia, Alberta, 1952

Date of sweeping	No. of bugs examined	% of nymphal instars					% of Adults
		First	Second	Third	Fourth	Fifth	
29-V-52	8	87.5	12.5	-	-	-	-
3-V1-52	149	45.0	23.5	23.5	8.0	-	-
17-V1-52	460	22.6	28.9	33.3	10.2	5.0	-
2-V11-52	356	5.4	8.1	19.5	27.4	35.8	3.8
8-V11-52	204	0.9	2.9	19.3	31.4	30.4	15.1
10-V11-52	124	0.8	4.0	7.3	25.0	46.8	16.2
14-V11-52	289	2.1	2.1	7.3	14.9	34.6	39.0
11-V111-52	67	-	-	-	1.5	4.5	94.0
19-1X-52	15	-	-	-	-	6.7	93.3

instar nymphs appeared abnormally large when compared to previous records.

It is shown in table 5 that there is an evident second increase in the percentages of the early instars in mid-July. This may be caused by one of several factors. On July 1 and 3 actual counts were extremely low. These low counts cannot be explained but were probably the result of sampling error. When transforming small numbers to percentages, variations are magnified. These two sets of percentages are slightly confusing but do not mask the general developmental patterns. Only 13 days elapsed between counts of June 29 and July 12. In that short period it was impossible for another generation to develop especially because no adults had as yet been taken. A comparison between percentage figures of June 29 and July 12 reveals the natural trend of development for that period, as verified by 1952 results.

An examination of first instar percentages reveals that hatch continued until some time after July 17. Rate of hatching would be affected by weather, unfavorable conditions suppressing it and favorable conditions resulting in another surge. This factor could affect the relative percentages too.

On June 18, 1951, A. superbus were found infesting an alfalfa seed-field at Scandia, Alberta, in numbers large enough to warrant future study. On the other hand May 29, 1952, marked the first occasion of the year when any superb plant

bugs were captured or seen. In 1953 the first nymph was taken on June 1, a first-instar specimen; previous sweepings on May 28 resulted in no Adelphocoris bugs being taken. All the bugs captured in sweeps on August 17, 1953, were adults.

C. HOST PLANTS

Alfalfa is the principal host plant of the superb plant bug. Sorenson (1946) reported that repeated efforts to collect it from other likely host plants, both native and cultivated, within the state of Utah had failed. Other research workers have taken it from other host plants at various times, however. Gillette and Baker (1895) took the bug on Senecio douglassi at Fort Collins, Colorado from June 23 to August 25 and September 27. Crevecoeur (1903) found it on weeds in timber at Onago, Kansas. Eyer and Medler (1942) stated that in irrigated valleys of southern New Mexico, A. superbus was among the most important pests of cotton while Stevenson and Kauffman (1948) reported that in Arizona the control of A. superbus and other mentioned pests was the most serious problem in cotton growing.

The objective of this section of research was to find any plants in southern Alberta, either cultivated or native that were serving as alternative hosts for the bug and that, as such, were natural reservoirs for infesting alfalfa grown in new agricultural areas.

Methods and Procedure: During the seasons of 1951 to 1953 a great many possible host plants were examined for A. superbus specimens by means of visual observations and sweeping. Plants harboring these bugs were examined in the laboratory for signs of oviposition, while the captured bugs were caged over plants of the same species in an attempt to induce feeding and oviposition.

Results: In only two instances during the three seasons were the bugs found on any host plant other than alfalfa. During 1952 a small population of the bugs were found on a patch of Canada thistle, Cirsium arvense (L.) Scop., on the prairie, approximately a mile from any alfalfa. When first seen only one late-instar nymph was taken, the rest being in the adult stage. Three or four gravid females taken from this location laid over 100 eggs in a Canada thistle plant on which they had been caged in the laboratory. They also laid some eggs in stems of alfalfa, sow thistle, Sonchus arvensis L., and lamb's quarters, Chenopodium album L., when caged with these plants.

A random sample of stems taken in late fall from the thistle patch on which the population had been found, proved to have a number of over-wintering superb plant bug eggs in them. None of the eggs hatched in the laboratory. Widths of stems chosen for oviposition sites were comparable to those widths chosen by others of the species in the alfalfa fields. During 1953

various stages of the species have been obtained by sweeping the above mentioned thistle patch.

On July 24, 1953, two adults were observed on a bull thistle plant, Cirsium sp., on the prairie in the Hays area. This location was 10 miles or more from any blooming alfalfa.

IV CONTROL OF ADELPHOCORIS SUPERBUS UHL.

Two methods of control were tested against A. superbus in southern Alberta. Experiments were carried out in 1951 and 1952 to test the effects of new insecticides on nymphs and adults. Also in 1952 an experiment was carried out to test the effect of burning on the overwintering egg stage. The second chemical control test was super-imposed on the burning experiment.

Research done by Hughes (1943) and observations reported by Hobbs (1948) concerning field burning gave promise that this form of control would prove very effective. It was necessary, however, to establish an alternative chemical control for late, wet springs when burning was impossible and also for those situations where economic populations built up unnoticed.

A. CHEMICAL CONTROL 1951

This experiment was begun on June 18 in a seed-alfalfa field owned by Mr. D. Cox, Scandia. On that date the estimated popula-

tion of superb plant bugs determined from 200 sweeps, averaged 4.9 per sweep. The season was too advanced to burn the field, so two insecticides, which had given good control of Lygus spp. were tested. Toxaphene had been recommended for use on flowering alfalfa by the staff of the Lethbridge entomological laboratory because it had been reported by others to be one of the least toxic insecticides to bee pollinators. This insecticide, at two rates of application, was compared with DDT which, though widely recommended for alfalfa pest insects, was also considered by many to be more toxic to bees.

Methods and Procedure: The experiment was set up in a randomized block, with four replicates. Each plot was 300 feet by 27 feet. Plots were set out in a single row to simplify spraying and to minimize damage done to the surrounding alfalfa during spraying operations. The insecticides were formulated from emulsion concentrates and applied with a boom-type, tractor-mounted, low pressure sprayer. Amounts of insecticides applied were determined by removing and measuring the amount of liquid remaining in the sprayer after a thorough coverage of each plot with a known concentration.

Applied treatments were as follows:

Toxaphene 1 - 0.4 pounds actual per acre.

Toxaphene 2 - 0.8 pounds actual per acre.

DDT - 0.3 pounds actual per acre.

Check - untreated.

Spraying was done late in the afternoon of June 29. The day was calm and warm, and drift was at a minimum. The boom was set approximately 10 inches above the alfalfa which gave a good coverage of the plants. Because the important pollinator Megachile perihirta had not begun to fly at this date (Hobbs and Lilly, in press) spraying was done during the day.

Assessment of the efficiency of the insecticides was to be based on two criteria, population data obtained by sweeping and seed yields determined by quadrat-sampling. Because the alfalfa field dried up from lack of irrigation water, it was not harvested. The yield samples were negligible in size and no significance was attached to the data obtained from them.

The writer agrees with the conclusions reached by De Long (1932) and Gray and Treloar (1933) concerning the faults of sweeping. However, it presents the only practical way of sampling active insects in a crop on a large scale, and so it is used in this research with the realization that the counts obtained are merely rough estimates of the true populations.

Fifty sweeps were taken on each plot immediately prior to spraying. Subsequent sweeps were taken on July 1, July 17, and September 7. Sweeping was done with a standard 14-inch-diameter sweep net. A full-arm sweep was taken every two paces as the

collector walked briskly into the wind and as nearly as possible toward the sun. The bag and its contents were then sprayed with carbon tetrachloride and the catch stored in individual cardboard containers for future identification. At no date was the same area within plots sampled twice.

All the common pests and predators found in the samples were counted and recorded separately. Their numbers were further subdivided under nymphs and adults. A. superbus kill data were analysed statistically.

Results: Insect populations within the plots remained at a low ebb throughout the season as a result of the gradual drying out of the alfalfa. No pest species other than A. superbus approached economic importance and the only predator taken in any numbers was Nabis ferus (L.), (Nabidae, Hemiptera).

The total numbers of superb plant bugs captured on each plot on each of the first three sweeping dates are reported in table 7. All bugs captured on the first two dates of sweeping were nymphs. Numbers varied considerably on individual plots.

Highly significant reductions in superb plant bug numbers were noted on treated plots 48 hours and 18 days after spraying. There were no significant differences among the insecticidal treatments however. Counts made on September 7 were not considered because the bugs had reached the adult stage and were moving freely about the field. In the nymphal stages there is

Table 7

Numbers of Adelphocoris superbus swept from plots during chemical control test, Scandia, Alberta, 1951. (50 sweeps per sample)

Replicates	Pre-spray Counts				Post-spray Counts							
	June 29				July 1				July 17			
	DDT	Tox.1	Tox.2	Check	DDT	Tox.1	Tox.2	Check	DDT	Tox.1	Tox.2	Check
1	147	110	245	311	0	0	0	112	12	40	43	171
2	137	165	132	107	0	4	2	120	7	19	6	158
3	75	91	121	92	0	2	0	81	15	18	10	58
4	100	108	101	96	0	7	0	24	18	22	6	36
Average counts					0	3.3	0.5	84.3	13	24.8	16.3	105.8
F (treatments)						14.1**				6.98**		
F (replicates)						0.9				1.62		
LSD (.05)						35.3				53.3		

no extensive migration within the field.

All three insecticidal treatments, DDT at 0.3 pounds actual, and Toxaphene at 0.4 pounds and 0.8 pounds actual per acre gave excellent control of the superb plant bug, even though applied at much lower dosages than are recommended for related insects.

On July 17 most plots showed an increase in numbers of A. superbus over the previous counts of July 1. Because the bug has a long hatching period of more than 40 days (table 6) it is probable that most of the increase resulted from eggs hatching some time after the insecticides had been applied.

B. CONTROL BY BURNING AND CHEMICALS, 1952

A second field in the Scandia area, owned by Mr. Taylor, was chosen as the site for a combined chemical and burning experiment against the superb plant bug in 1952. Sampling in the late summer of 1951 revealed an adult population of 1.86 bugs per sweep. The seed yield had been so poor that the stand was left uncut and thus gave promise of a thorough spring burn.

The chemical test was super-imposed on the burning test to check the previous year's results of A. superbus control and also to segregate the amount of damage done by A. superbus as compared to that done by Lygus spp. In theory, burning would control the superb plant bug while burning and chemical would

control both major pests, which should have resulted in differences in seed yields. Because this field also dried up for lack of moisture as the experiment progressed, lush growth and subsequent high Lygus populations did not materialize. Insecticidal controls on the burned area therefore gave no significant yield increases over checks. For this reason the results attributable to chemicals and to burning were analysed and interpreted separately with no attempt made to evaluate the interactions of the treatments.

Methods and Procedure: Two areas within the field, each four acres in size and separated by a 40-foot buffer were staked out on the north-east corner of the farm which bordered the Bow River. A split-plot design would have been an appropriate experimental set-up but this was impractical because of the difficulty of burning small plots. The large four acre block adjacent to the river was burned; since the prevailing wind is from the south-west hazards of fire were minimized. As a further precaution a two-furrow fireguard was ploughed around the perimeter of this area. On each four-acre block, twenty small plots, each 32 feet by 273 feet, were staked out in a single row for the subsequent insecticidal test.

Populations on the two blocks and the general population on the field were estimated by sampling for egg numbers. Late in

the fall of 1951 and early in the spring of 1952, randomized square-foot samples of standing dead plants were examined for eggs. Thirty samples were taken from similar locations within each of the two blocks and another general collection of 40 samples was taken to estimate the general population in the field.

Egg counts from 100 one-square-foot plant samples gave a mean of 12.8 eggs per sample ($S_{\bar{x}}$ =1.26). Comparison of egg samples from the two large blocks by means of the t-test showed that A. superbus populations, on the basis of egg counts, were similar.

During the week of April 21 to 25 when the first green growth was just visible at the alfalfa crowns, the designated block was given a thorough burn. The fact that the dead plants were still standing resulted in a cleaner, more complete burn than would normally be expected.

Sweeping samples were taken at irregular intervals on the alfalfa outside the immediate experimental area, until it was assumed on June 17 that a large percentage of superb plant bugs had hatched. On June 21 and 22, insecticides were applied to the plots. A new type of low-pressure, trailer-mounted sprayer with a 32-foot boom was used which resulted in application of slightly higher concentrations than in 1951. There were five replicates per block, each containing the following randomized treatments:-

Toxaphene 1 - 0.5 pounds actual per acre.

Toxaphene 2 - 1.0 pounds actual per acre.

DDT - 0.45 pounds actual per acre.

Check - untreated.

Insecticides were applied on two calm, warm afternoons. The important pollinator, M. perihirta, had not reached the peak of flight activity at this time (Hobbs and Lilly, in press), so its numbers were probably not adversely affected.

First post-spray counts were not taken until July 2 because of heavy rains and cool weather in the district. Subsequent sweepings were taken on July 14, August 11, September 4 and September 19. The sweeping technique was similar to that used in the 1951 experiment and data on the same common species were recorded. Data on A. superbus were analysed statistically.

Seed yield samples from all plots were taken on September 9 to 11. Six one-square-yard samples were taken at random from similar locations within each plot. These samples were bagged individually, then threshed, weighed, and analysed statistically.

Results: (a) Burning: Spring burning affected both flora and fauna. Striking differences between the alfalfa on burned and unburned areas appeared soon after burning. Alfalfa on burned-over land was temporarily set back but soon overtook the unburned stand. Burned-over alfalfa plants were healthy,

producing dark green, lush vegetation and profuse bloom. Plants on the unburned portion were pale green, spindly and produced short racemes with small florets. When the farmer failed to irrigate, differences were accentuated, the burned-over plants exhibiting much more resistance to drought.

Seed yields were just as contrasting. Samples from check plots on the two areas were compared. Yields on burned-over check plots averaged 77.4 pounds of clean seed per acre while the unburned checks averaged 5.5 pounds per acre. The owner harvested only the four-acre burned block and a few other small burned patches, leaving most of the 55 acre field unharvested for the second consecutive year. From the four acre block he obtained 320 pounds of uncleaned seed.

Check plots were sampled on July 14 by plant pathologists for incidence of disease. Burning reduced black stem, yellow leaf blotch and leaf spot from moderate to only a trace.

The main insect species on the unburned block were Adelphocoris superbus and Lygus spp; together with predators Sinea diadema (Fabr.) (Reduviidae), Phymata fasciata (Gray) (Phymatidae), Nabis ferus (L.), and Nabis subcoleoptratus Kirby (Nabidae. On the burned block there were no A. superbus, S. diadema, or P. fasciata recorded until the bugs became adults. Aphid populations were very large. Associated with these aphids

were their more specific predators. Coccinelid larvae and adults were present in large numbers, as were nymphs and adults of N. ferus. Chrysopa harrisii var. externa Hagen (Chrysopidae) was present in smaller numbers. The population of N. ferus increased throughout the season until by mid-September they were the most abundant insects captured by sweeping, even surpassing the aphids in numbers (See table in Appendix).

A comparison of A. superbus numbers taken in pre-spray sweeps was very convincing. A. superbus nymphs captured in 1000 sweeps on the unburned block totalled 2650, while on the burned area only 1 nymph was taken in 1000 sweeps. Counts on the unburned block would have been much higher if hatch had been completed. The count on the burned block never increased beyond 2 per 1000 sweeps until the bugs reached the adult stage.

(b) Chemical Control: Total counts of A. superbus for the first three dates of sweeping are recorded in table 8. Later counts were not considered because the majority of bugs captured were adults. Included with the table are the results obtained from a statistical analysis of the data.

This chemical test, although not as conclusive as that of 1951, did verify the previous results. The analysis of variance of counts taken on July 2 showed highly significant difference

for insecticidal treatments over checks but no significant differences among treatments.

All treatments were equally effective. An analysis of figures obtained on July 14 gave no significant difference for treatments as compared with checks. Late hatch, or high mortality of the bugs because of other causes e.g. drought of the plants probably obliterated any significant differences due to insecticides. Actual counts on treated plots were still lower than on check plots however. Variations of counts within replicates were significant on both dates of sweeping.

Insecticidal treatments gave no significant increases in seed yields either on the burned or unburned blocks. Seed yields were negligible on the unburned plots because of lack of moisture, and control of A. superbus did not result in an increase of seed. On the burned-over area, because no economic insect population was present, applications of insecticides did not affect yields either.

Statistical analyses of sweeping counts showed that the predators P. fasciata and S. diadema were not adversely effected by the insecticides. (See tables in Appendix). This may be the result of late hatching.

Table 8

Numbers of *Adelphocoris superbus* swept from plots during chemical control test, 1952, Scandia, Alberta. (50 sweeps per sample from unburned plots)

	June 17				July 2				July 14			
Replicates	DDT	Tox.1	Tox.2	Check	DDT	Tox.1	Tox.2	Check	DDT	Tox.1	Tox.2	Check
1	50	114	45	153	8	36	18	110	88	43	32	61
2	72	301	307	130	17	39	45	75	43	14	33	99
3	130	87	112	90	9	12	11	23	6	13	8	8
4	152	185	136	254	21	25	1	77	2	9	12	46
5	22	125	99	87	0	5	4	42	0	3	6	25
Averages					11	23.4	15.8	65.4	27.8	16.4	18.2	47.8
F (treatments)						11.39**				2.92		
F (replicates)						3.40*				5.70**		
LSD (.05)						22.7				-		

V DISCUSSION

A. Bionomics

The overwintering eggs of A. superbus were found in alfalfa stems. The results cited under the section on oviposition, indicated that the females of A. superbus lay their eggs in soft square stems. The eggs were found in various portions of the plants.

Sorenson (1932) reported that in alfalfa fields A. superbus females had been observed to lay their eggs in the alfalfa stems, usually below the upper 3 or 4 inches. Sorenson (1946) found that in rearing cages 35% of 444 eggs were laid in the basal 4 inches of the stems and 25% in the apical one-inch portion. Hughes (1943) working with a close relative the alfalfa plant bug, Adelphocoris lineolatus Goeze, found that the over-wintering eggs of this bug were laid closer to the stem base and that the insects seemed to choose the older and less succulent growth in late summer, possibly because it provided more protection for the over-wintering eggs.

Young growing alfalfa stems and the upper portions of more mature plants owe their square shape to the presence of four separate bundles of strengthening collenchyma, one at each corner (Stover, 1951). Between these bundles the tissue

is largely parenchyma and as such is easily penetrated. As the stem matures the cambium begins to lay down secondary tissue which has the effect of rounding the stem. Lignin, which replaces pectic substances in the cell walls at this time, gives the stem a very tough wall which is very resistant to penetration.

Differences in the sites of oviposition as seen among the results presented in Table 2, and between these results and those recorded by Sorenson (1946) can no doubt be credited to the variations in maturity and degree of lignification of the seed plants at the time the bugs were ovipositing. In many of the alfalfa seed growing areas of the United States a hay crop is first removed before leaving the field for seed. The second growth stems are not as extensively lignified as are those in southern Alberta where first-growth is left to produce seed because of a much shorter season. This fact would undoubtedly result in eggs being inserted in different parts of the plants. The only eggs recorded in southern Alberta that had been laid within the basal four inches of stem, were eleven that were found in a secondary stem which was square and pliable for its entire length. In this particular stem, 68 eggs were laid within a length of four inches.

The great percentage of eggs that are laid in the upper parts of the alfalfa plants will remain in those portions of the plants that are spread back on the field by the combine. There they will over-winter, protected by the surrounding stem, debris and snow cover. In this favored position the emerging nymphs have a readily accessible source of food in the next year's growth. The tests on cold-hardiness indicated that winter mortality varies with weather conditions, micro-habitat and length of time of exposure. The species, however, seems well adapted to its environment in southern Alberta and is probably in no danger of being eliminated by variable weather conditions. The eggs go into an obligatory diapause that prevents the disaster that would follow late fall hatch. Since the eggs are laid over a relatively long period of time and yet show no visible embryological development at the onset of winter, it would appear that diapause occurs almost as soon as the eggs are laid. It is probable that natural selection in Alberta has eliminated those individuals, as found within the species in Utah, whose eggs develop and hatch without an arresting period. Summers in southern Alberta are too short to allow two generations per year to develop. While it was true that counts at more regular and more frequent intervals would have presented a fuller picture of the nymphal

development, the progression from nymphs to adults was evident and the theory that the bug had only one complete generation a year in southern Alberta was verified. Sorenson found that, under caged conditions in Utah, A. superbus required 9 and 21.5 days for the preoviposition and incubation periods respectively. Applying these findings to the Alberta data would mean that if there was a second generation the first young nymphs of the second generation would have been taken more than 30.5 days after the first adults were seen. In 1951 this would have occurred about August 12, but in sweepings on August 13 fourth-instar nymphs were the youngest taken. In 1952 young nymphs should have been appearing about August 2. Counts on August 11 showed that the youngest nymphs were fourth-instar and that the proportion of these was very small (1.5 per cent).

In southern Alberta, the species does have a very long hatching period. All results indicated a hatching time of more than one month. Sorenson (1946) reported that the earliest hatching of overwintering eggs in Cache Valley, Utah, occurred on May 5, and that the length of the incubation period of 433 eggs during July and August varied from 16 to 27 days. Oviposition was found to take place from June 15 to mid-September. These reports on the bionomics of the species in Utah showed that the first generation developed much earlier

than in southern Alberta, and accounted for the assumption that two complete generations could be produced in one season there.

Because the bugs have such a long hatching period, certain observations should be carried out before attempting to control them with chemicals. Insecticides will give better results if application is withheld until hatching is as nearly complete as is possible before the peak of pollinator activity is reached. If applied at too early a date, a second application may be needed to control later hatching nymphs. It would be best to apply the insecticide after sweeping had revealed that the percentage of first-instar nymphs had drastically decreased.

B. Control

1. Burning

Thorough spring burning gave excellent control of the superb plant bug and also substantially increased seed yield. It did wipe out at least two valuable predators, S. diadema and P. fasciata. In late fall, overwintering eggs of both species were discovered in alfalfa fields, adhering in small clusters to various portions of alfalfa plants (figs. 4 and 5).

Burning had some effect on the early development of Nabis ferus, which appeared to be more specifically a predator of the pea aphid, Macrosiphum pisi (Kalt.). No N. ferus nymphs

Fig. 4 A group of Sinea diadema eggs adhering to the stem of an alfalfa plant. (photomicrograph approximately X30)

Fig. 5 A group of Phymata fasciata eggs adhering to the stem of an alfalfa plant. (photomicrograph approximately X25)

were taken in pre-spray or in the first post-spray counts on the burned plots but they were taken on the unburned plots. This would indicate that egg laying was retarded on the burned plots. The adults were among the first insects taken in the spring by sweeping alfalfa fields and they apparently overwinter as such. If they overwinter in the alfalfa fields they are killed by spring burning. If they entered the field in the spring they were attracted to the unburned portions which were more advanced than the burned over areas and were supporting populations of suitable prey. The situation was soon changed, however, when the aphid populations built up on the burned area and Nabis adults were attracted. The increase of both species was rapid.

Taylor (1949), when doing a life history study of Nabis alternatus Parshley in Utah, fed newly hatched nymphs on M. pisi and Lygus spp. adults, the average numbers of aphids and Lygus devoured per nymph being 80 and 29 respectively. He also reported that caged female damsel-bugs laid an average of 127 eggs per female. From this information the value of N. ferus as a predator of aphids and other pests seems apparent. The abundance of prey undoubtedly increased the reproductive capacity of the predators, as Balduf (1950) found when feeding individuals of Sinea diadema on adult flies of Drosophila

melanogaster (L.). By late summer the number of N. ferus present must have been a factor in reducing the aphids and other pests.

Effect of burning on the predator-pest inter-relationships would bear further investigation. Nymphs and adults of S. diadema, P. fasciata, N. ferus and N. subcoleoptratus, when confined, fed readily on A. superbus and Lygus spp., and must account in some measure for their control in the field, although probably none of them, and especially P. fasciata (Balduff, 1939), are very specific in their host relationships. Sorenson (1946) reported that there were no known predators or parasites of A. superbus.

Bolton and Peck (1946) observed a number of partially burned fields and noted that areas of good seed setting coincided with burned areas almost to a line. Their observations on height and vegetative vigor, however, indicated no difference in favor of the burned areas. They did suggest in part, that differences, particularly in seed yield, may have been caused by the fertilizer effects of the ash residue. It does seem probable that burning liberates nutrients and makes them readily accessible during early spring growth. Burning also reduced plant diseases and insect pests. The over-all effect was a healthier stand of alfalfa which put forth more and larger racemes for pollination.

2. Chemical Control

The effectiveness of low dosages of toxaphene and DDT against the superb plant bug indicates that this species is more susceptible to these insecticides than are Lygus spp. Much higher concentration and repeated applications of these two chlorinated hydrocarbons have been recommended for Lygus control. (Knowlton, 1947; Carlson et al., 1950). The two chemical experiments proved that one well-timed application of toxaphene or DDT at low concentrations will keep the superb plant bug in check. Toxaphene at both concentrations gave as good control as did DDT. It will therefore be recommended at the Lethbridge Field Crop Entomological Laboratory, Lethbridge, as a spray to control A. superbus in blooming alfalfa. If future research proves that DDT has no greater toxicity to bee pollinators than has toxaphene, it may be necessary to change the recommendations. Some have claimed that DDT has a longer residual action than has toxaphene, which would increase its effectiveness.

The action of the two insecticides on the pea aphid was interesting. Statistical analyses of aphid counts obtained on July 2 from burned and treated plots gave significant increases of treatments over checks. The LSD(.05) however proved that only the counts on the plots treated with low dosages of

toxaphene were significantly higher than counts on checked plots. A comparison of actual counts showed that numbers on DDT-treated plots were smaller than on check plots while numbers from both toxaphene 1 and toxaphene 2 plots were higher than from the checks. Populations on all plots showed increases over pre-spray counts however. An analysis of July 14 counts showed no significant differences between counts.

This trend seems to follow that suggested by Curtis and Davis (1952), although the differences in dosages would affect the results obtained. They treated M. pisi populations with DDT at 2 pounds actual per acre, toxaphene at 3 pounds actual per acre and Dieldrin at 0.5 pounds actual per acre. DDT reduced the population one week and four weeks after treatment. Toxaphene effected significant control of the aphid one week after treatment but four weeks after treatment surviving aphids built up their populations 518 per cent. A dosage of one-half pound of Dieldrin showed an increase population trend under significance the first week but a significant 466 per cent increase four weeks later. Observations made in 1950 in an alfalfa field in the Scandia area, which was treated with 1.5 pounds actual toxaphene per acre to control grasshoppers showed results similar to those quoted. On July 7 the population of M. pisi in the field averaged 4 per sweep. The insecticide was applied between July 10 and 13. On July 13 the aphids averaged

less than 2 per sweep but by July 18 they had increased to more than 20 per sweep and by July 24 had reached a count of more than 40 per sweep. (monthly report of Hobbs and Lilly at the Lethbridge Field Crop Insect Lab., June 26 - July 25, 1950)

The reason for this increase after the application of toxaphene is not known but the insecticide may stimulate reproduction in the aphids or it may seriously reduce the numbers of one or more valuable predators.

VI SUMMARY AND CONCLUSIONS

1. Overwintering eggs of A. superbus are described and illustrated.
2. Oviposition preferences are described and compared with related data compiled in the United States about the same species and a closely related species. In southern Alberta female bugs oviposit in square stems of second-growth alfalfa and in the upper tips and branches of first-growth alfalfa. Eggs are not laid in the basal portions of stems in southern Alberta but in alfalfa in United States they are. The difference seems to be that a hay crop is removed before the alfalfa is left for seed, in some of the States, which results in younger plant growth at the time of oviposition.
3. Eggs were tested for cold-hardiness in the laboratory and the results, together with field observations, show that the species is well adapted to its environment in southern Alberta in this respect.

4. An obligatory diapause protects the eggs from hatching in late summer and in the fall.
5. Data on the rate of nymphal development in the field are compiled for two consecutive seasons. There is only one complete generation in southern Alberta.
6. Canada thistle (C. arvense) is an alternative host plant. Gravid females will oviposit on other plants in the laboratory.
7. A. superbus is successfully controlled with low concentrations of toxaphene, (0.4 to 1.0 pounds actual per acre) and DDT (0.3 to 0.45 pounds actual per acre).
8. Spring burning is very effective for controlling the superb plant bug. It also reduces disease and produces a healthier stand of alfalfa.
9. A number of valuable predators, notably S. diadema and P. fasciata, overwintering in the egg stage are also wiped out by burning. Their effectiveness in controlling pest outbreaks is not known, however.

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Numbers of Phymata fasciata swept from unburned plots during chemical control test, 1952, Scandia, Alberta. (50 sweeps per sample)

	Pre-spray counts				Post-spray counts							
	June 17				July 2				July 14			
Replicates	DDT	Tox.1	Tox.2	Check	DDT	Tox.1	Tox.2	Check	DDT	Tox.1	Tox.2	Check
1	0	0	0	1	0	0	1	1	6	0	0	0
2	0	0	0	0	2	2	1	0	4	2	8	9
3	0	0	0	1	2	0	0	0	3	1	2	2
4	0	0	0	2	0	1	0	0	0	3	1	7
5	1	0	0	0	0	0	3	0	0	2	1	2
Total counts					4	3	5	1	13	8	12	20
F (treatments)						0.538				0.75		
F (replicates)						0.557				2.05		

Numbers of Sinea diadema swept from unburned plots during chemical control test, 1952. (50 sweeps per sample)

	Pre-spray counts				Post-spray counts							
	June 17				July 2				July 14			
Replicates	DDT	Tox.1	Tox.2	Check	DDT	Tox.1	Tox.2	Check	DDT	Tox.1	Tox.2	Check
1	0	0	0	2	0	0	0	2	1	0	2	4
2	0	0	0	0	4	0	0	0	6	8	7	5
3	0	0	0	1	2	0	0	2	0	7	5	3
4	0	0	2	0	1	2	2	0	13	6	15	8
5	0	0	0	0	0	2	0	1	11	1	10	13
Total counts					7	4	2	5	31	22	39	33
F (treatments)						0.9				0.79		
F (replicates)						0.3				4.104**		

Numbers of a pest and a predator recorded from sweeps taken on burned and chemically-treated plots. Scandia, Alta., 1952. (250 sweeps per sample = summation of 5 replicates)

Treatments	Pre-spray		Post-spray							
	June 17		July 2		July 14		Aug. 11		Sept. 4	
	Nym.	Total	Nym.	Total	Nym.	Total	Nym.	Total	Nym.	Total
				A. Macrosiphum pisi (Kalt.)						
DDT		606		1787		5114		427		114
Tox. 1		460		3101		5081		394		113
Tox. 2		740		2359		5244		330		113
Check		724		1943		4987		536		80
				B. Nabis ferus (Linn.)						
DDT	0	3	0	1	4	15	68	104	54	135
Tox. 1	0	0	0	3	4	19	110	144	90	217
Tox. 2	0	2	0	3	4	11	79	91	39	168
Check	0	0	0	4	1	17	85	111	52	173